Building Information Modelling (BIM) and Smart Cities: The Role of Governance, Regulations and Policies

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Abstract. Existing literature focuses mainly on the benefits of SCs, particularly the impact of technology, however, efforts to explore the current challenges in implementing technology in SCs have been limited. The purpose of this research is to investigate the benefits and challenges of BIM in the development of SCs and to examine the role of governance, regulations, and policies in SCs; determining if the extant initiatives are sufficient or not. A sequential explanatory mixed-methods design approach was employed. Data has been gathered from 54 questionnaires, followed by semi-structured interviews to gain additional qualitative data. The main quantitative and qualitative findings show that data privacy and security are the biggest technological challenges in SC development and that further regulation and legislation is required to protect citizens against privacy threats. The results of this work can be useful to professionals and policy makers working on SCs as well as researchers to better understand the current gaps.

Keywords: Smart city · Technology · Governance · Regulation · Policy

1 Introduction

Cities have a major responsibility in opposing climate change, and the implementation of innovative smart technologies is an important aspect in reducing pollutants and emissions and enhancing sustainability within cities [1]. A city can be defined as smart when expenditures in human and social capital and transport and technological infrastructures, drive economic development and better standard of living, by wisely managing natural resources, via collaborative governance [2]. Smart Cities (SCs) can help tackle the issues created by growing urban populations and hastened urbanisation [3], therefore championing the UN Nations 2030 Agenda Sustainable Development Goal (SDG) 11. The aim of this goal is to transform cities into safe, resilient and sustainable places, whilst protecting the environment [4]. Digital technologies are facilitators of SCs and can be used by cities to confront environmental matters, distinguish the key trends, and uncover variances of technical and policy levels [5]. The main technological drivers behind SCs include Building Information Modelling (BIM), the internet of things (IoT), blockchain, big data, artificial intelligence (AI), cloud computing and robotics [6]. While technology is beneficial to the sustainable development of SCs, certain challenges arise through

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its application. These include disruption to the labour market, maintaining social cohesion, inclusiveness and solidarity, and questions around security and privacy [6]. The government cannot solely tackle these issues; therefore, corporations and new citizen cooperatives should exercise their social and corporate responsibility by advocating policies and regulations that resolve social difficulties [7]. Current research demonstrates that technological advancement is driving SC realization, however, the obstructions and complications in implementation are indeterminate. This paper uses mixed-methods research to combine quantitative results and qualitative findings to develop a more thorough discussion around the research questions. It explores the benefits and drawbacks of the key technological drivers in the development of SC, and enquires into how regulations, policies and governance can support technology in the advance of SCs.

2 Literature Review

2.1 Benefits of the Key Technological Drivers for Smart Cities

Alongside growing environmental demands and infrastructure requirements cities are increasingly pressurised to provide an improved quality of life (QoL) for citizens. Data and digital technologies are employed in SCs with the intention of enhancing QoL [8] as more complete and instantaneous data allows authorities to observe events as they occur, comprehend how requirements are shifting and react with quicker and more economical solutions [9]. BIM offers a valuable source for SC as it can comprise several types of data including geometric data, time-related data, geographic data, resource budgets and building properties; this allows specialists to work together during the entire life cycle of assets [10] that form the SC. As BIM develops to facilitate SCs through various software applications, open standards such as Industry Foundation Classes (IFC) and CityGML are of increasing importance for the interoperability of data [11]. Moreover, as BIM is being mandated by several governments globally such as the UK, Singapore, Italy, Germany and Peru, there is greater motivation to explore BIM for cadastral reasons [12]. Building automation systems can reduce the greenhouse gases emitted by buildings [13]. Emissions from vehicular traffic can also be reduced with smart traffic lights, congestion charges and other mobility applications [14]. Moreover, communicating real-time air-quality data with citizens via smartphone applications allows them to take appropriate precautions to diminish adverse health effects [15]. SC applications that alleviate traffic jams through smart syncing of traffic lights can lessen bus journeys significantly whilst real-time navigation warns drivers of disruptions and provides them with a quicker route [16]. Additionally, digital signage and mobile applications could provide commuters with real-time updates about disruptions and allow them to modify their journeys on the spot [17]. Although technology is not an instantaneous solution for crime, authorities can use data obtained from SC applications to employ limited resources and staff more efficiently [18] and applications such as real-time crime mapping can use statistical investigation to highlight trends [19]. The installation of IoT sensors on current physical infrastructure can assist personnel in executing predictive maintenance and repairing snags before they cause failures or interruptions [20]. E-career centres and digital hiring platforms create more effective hiring procedures and attract more unemployed citizens into the labour force [21] and data-directed formal education and online retraining

courses can augment collective skill-base of a city [22]. Lastly, the digitisation of government operations including business licensing, permitting and tax filing can save time spent by local businesses on bureaucratic paperwork, thereby promoting a more effective and enterprising business environment [23]. Table 1 summarises the main benefits of technological drivers in SCs.

2.2 Challenges Arising from Technology Use in Smart Cities

Although SC technology improves and benefits the lives of urban residents, there are notable risks and challenges [24]. Significant matters of concern in the smart environment are the management of the vast quantities of data and preserving and protecting the privacy of citizens [25]. If data conservation is not appropriately managed, society could face severe repercussions, including the disturbance of services and the downturn of community life [26]. The internet is the main driving force behind the functioning of a SC; however, centralisation and a city's connection are a cause for risk and vulnerability as attackers use the internet connection as a channel for their attack [27]. Such attacks essentially halt an entire organisation for many hours, causing train disruptions, bridge closures and negative impacts on citizens' lives and the economy. Cybersecurity is therefore an imperative requirement to protect and maintain the benefits of SC technologies [28]. Moreover, the implementation of technology in SC is complicated and could pose an obstacle if not executed correctly [29]. Technological understanding and proficiency vary amongst citizens, which could create social exclusivity and hierarchy if citizens are not engaged with or educated throughout SC implementation [30]. Another significant challenge is the high cost of using smart technologies to modernise and improve infrastructure, hence governments must explore all avenues for funding and financing to develop a suitable business model [31]. Lastly the various solution and device types, with different service-specific platforms creates fragmentation, resulting in interoperability challenges [32]. Table 2 summarises the main challenges of technological drivers in SCs.

Table 1. Benefits of technological drivers in SCs

Technology benefits	Source
Better traffic flow	16, 17
Improved energy efficiency	13, 14
Augmented digital equity	22
Safer cities	18, 19
Renewed infrastructure	20
Efficient public services	23
New economic development activities	21, 23
Enhanced citizens' quality of life and health for citizens	8, 15

Table 2. Challenges of technological drivers in SCs

Technology challenges	Source
Security and hackers	26, 27, 28
Privacy concerns	25
Complicated implementation of infrastructure	29
Engaging and educating citizens for social inclusivity	30
Legislation and policies	33, 34
Funding and business models	31
Interoperability	32

2.3 Role of Governance, Regulations and Policies in Smart Cities

Cities become more productive with the application of SC policies [3], and there is numerical proof that demonstrates a positive correlation between the application of SC policies and urban economic operation [33]. Another benefit of SC policy is the stimulation of innovation that grows a city's pool of knowledge, one of the key acknowledged drivers of economic growth [34]. The use of BIM for SCs can be associated with smart governance and policy development. The IFC is an open file format established by buildingSMART alliance, used for architectural, building and construction data, that is compatible with numerous BIM tools [35]. Therefore, the use of data as a source for 3D cadastre has been investigated since the classification founded on 3D models is highly significant for SCs [36]. Similarly, the best know data format for 3D City Models, that provides semantic information and detailed data for geospatial and city objects, is the CityGML [37].

For SC proposals to obtain the required investment to be realised, legal and regulatory structures need to be up to speed with latest technologies [38]. Due to the disconnection between legal frameworks, citizens' needs and technologies, SCs encounter various legal and practical issues in employment of their innovative policies [39]. Furthermore, the lack of precise or adaptable legal frameworks for SCs could defer or hinder some of their programmes [40]. SCs face many challenges that exceed the competencies, proficiencies and reaches of their conventional organisations and their established forms of governing, hence necessitate new and inventive methods of governance [41]. Under the term smart governance which includes these innovative governance methodologies, the government administers and applies policies towards the augmentation in citizens' QoL, through information communication technologies (ICTs) and by purposefully including and working together with stakeholders [42]. There are several standards published by the International Organisation for Standardisation (ISO) relating to SCs. With regards to city services and QoL, standards under ISO 37120:2018 enable the implementation of smart city policies, technologies, and practices whilst the purpose of ISO 37122 (Indicator for Smart Cities), published in 2019, is to assess the performance of SCs regarding meeting

sustainability goals throughout city advancement [11]. ISO 19152 Land Administration Domain Model (LADM) supports the creation of geographic information systems (GIS) as well as spatial planning, suggesting the assimilation of spatial planning and land administration environments [11]. The standard for BIM to GIS conceptual mapping is ISO 19166. Moreover, the purpose of the ISO/TR 23262 standard is to increase interoperability between geospatial and BIM domains, particularly to align BIM and GIS standards, whilst ISO/TS 19166 outlines the theoretical basis for representing data from BIM to GIS [43]. Nonetheless, the numerous questions surrounding concerns about government leadership and collaborative models of governance call for further research [44].

3 Methodology

This section presents the research methodology for the mixed methods-based theory investigation concerning the use of disruptive and innovative technologies in SCs. This method allows for a broader and more comprehensive insight into the various benefits and drawbacks of technologies used in SC implementation and presents a way to expand on theory using the data. When the aim of research is to analyse certain situations and outcomes by depending on the observations and opinions of relevant professionals, a qualitative study is applicable [45]. On the other hand, when the aim of research is to comprehend the connections and consequences between elements, a quantitative approach is more applicable [46].

Since the intention of this study is to analyse the benefits and drawbacks of technology use in SCs and explore how governance, regulations and policies and can address the privacy and security challenges, a mixed methodology was selected.

Sequential mixed-method research describes a study where the research stages take place consecutively, with one stage either developing from or following the other. Both the research questions and methodology employed in the second stage are contingent on the previous stage [47]. In the case of this study, analysing journal articles, reports and books performed first literature review. The purpose of the literature review was to identify the benefits and challenges of technologies that informed the quantitative research in the form of a research questionnaire, developed by a qualitative follow-up interview.

Study participants were UK-based and from within the science, technology, engineering and mathematics (STEM) field, with either an expertise or interest in innovative technologies within SCs. Career examples included, but were not limited to, engineers, project managers, architects, urban planners and researchers. Before commencing the study and contacting participants, approval from Ethics Committee at the University College London was obtained. Consequently, in May 2020 the potential participants were sent a link to the online questionnaire via email and LinkedIn messaging. Upon completion of the questionnaire, participants had the option to share their email address to arrange a follow up interview in July 2020. Interviewees were selected from the questionnaire study participants who expressed their interest in discussing their answers further. Interviews took place virtually via Zoom and were recorded with the interviewees consent. Notes were taken during the interview, but the recordings were used to fill

in any information gaps. The informed consent form was available for the participants to read and agree to before answering the questionnaire. Moreover, all responses obtained from the questionnaire were anonymous, minimising confidentiality risks. Additionally, data was stored on a protected server.

The quantitative study offered a good base for the successive interviews and hypotheses from the quantitative phase were carried forward to the semi-structured interviews. No challenges were encountered at the interface between the quantitative and qualitative phases. The qualitative study was used to confirm the results of the quantitative study. Therefore, the feedback from how the investigation was interpreted informed the interpretation of the final results (Fig. 1).

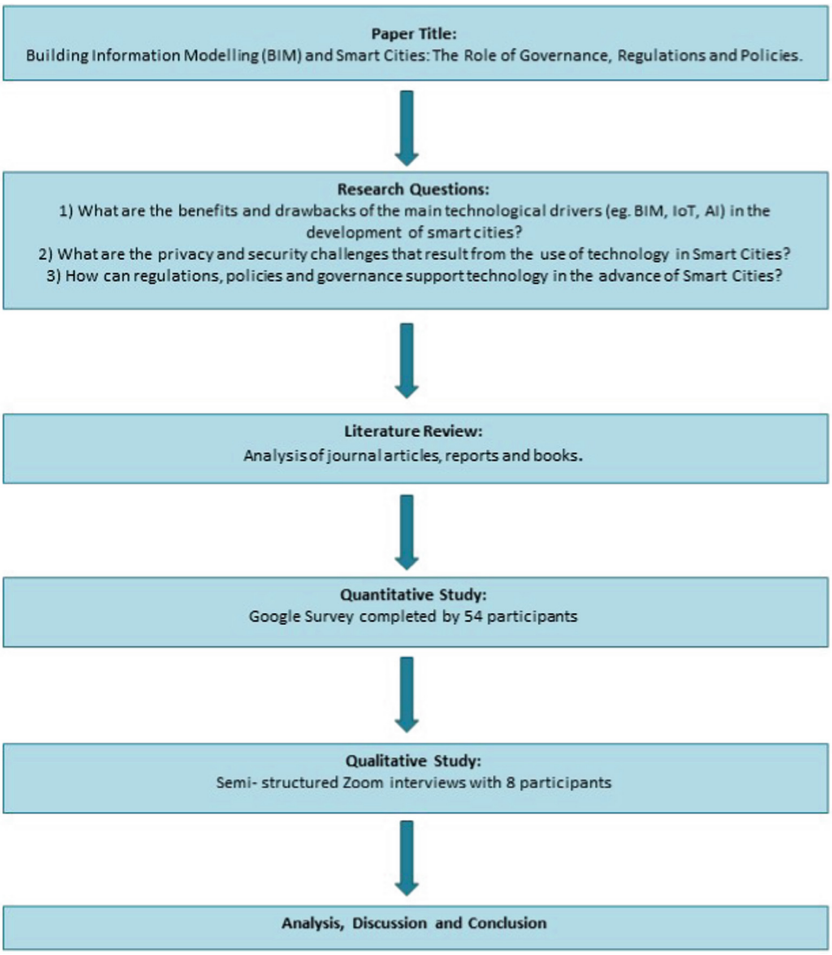

Fig. 1. Research methodology flowchart

4 Results

This section presents the quantitative study from the questionnaire followed by the results of the qualitative study from the interviews.

4.1 Quantitative Results

The online questionnaire was completed by 54 participants, whose job titles ranged from managing director and innovation lead to assistant professor and research intern. The top three represented business areas were engineering (20.4%), multidisciplinary (16.7%) and consulting (14.8%). The total years of experience in each of the sampled participant's respective field varied. Majority (44.4%) of the participants had over 10 years of experience. While 31.5% of the participants had 5–10 years of experience 24.1% of the participants had 1–5 years of experience and only 3.7% had less than one year of experience.

4.1.1 Understanding the Relevance of Smart Cities

Firstly, it was asked to rank the most relevant areas to Smart Cities. Over 50% of participants ranked the pertinent SC areas determined from the literature review, in the following order from most relevant to least relevant: people, environment, governance, economy, mobility and living (see Fig. 2). It was also asked which of the challenges ascertained from the literature review could be tackled through SC implementation. Over 90% of participants believed that air pollution and urban congestion challenges can be tackled and approximately 50% of participants also considered that water shortages could be alleviated, and safe energy access supported through SCs. In contrast, only a third of participants thought that housing shortages and crime could be reduced and less than 20% of participants deemed that SC application could confront inequality and social segregation challenges (see Fig. 3).

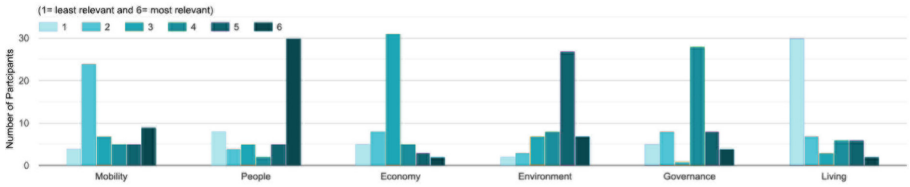

Fig. 2. Relevant areas in SCs

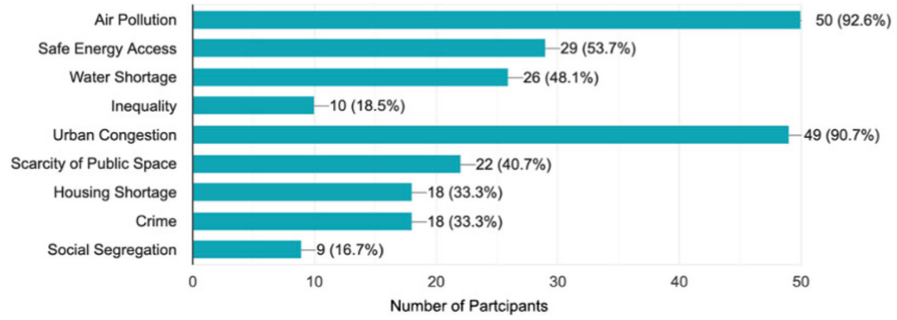

Fig. 3. Challenges that can be tackled through SC implementation

4.1.2 Technological Drivers in Smart Cities

When asked about the relevant of the numerous SC technologies discerned in the literature review, over 70% of participants considered big data, geospatial technology and IoT as being essential in SC development. Approximately 55% of participants considered robotics and augmented and virtual reality (AR and VR) to be quite significant technological drivers. A total of 28% of participants considered blockchain to be quite significant or essential, whereas the majority (55%) deemed it to be neutral on the Likert scale from not applicable at all to essential. Conversely, approximately 50% of participants regarded autonomous vehicles and drones to less applicable in SC development. It is worth nothing that the only four technologies that some participants considered to be not applicable at all were robotics, blockchain, autonomous vehicles and drones and AR and VR. Moreover, it was less than 6% of participants that considered either one of the four technologies to be not at all applicable.

With regards to the impact of technology on the eight SC benefits identified in the literature review, the percentage of participants that ranked technology as having the most influence on each benefit is as follows: better traffic flow (63%), renewed infrastructure (50%), efficient public services (30%), improved energy efficiency (22%), new economic development activities (13%), better citizen QoL (13%), augmented digital equity (7%) and safer cities (5%). In terms of the technological challenges identified in the literature review, the percentage of participants that ranked each challenge as the biggest challenge is as follows: privacy concerns (79%), security and hackers (65%), funding and business models (13%), ensuring social inclusivity (11%), engaging and education citizens (11%), interoperability (11%), legislation and policies (9%) and complicated implementation of infrastructure (7%).

4.1.3 Challenges Resulting from the Use of Technology in Smart Cities

The literature review demonstrates that there are number of challenges that arise from the use of technology in SCs. Participants were asked to rank these challenges on a Likert scale from 1 (Minor challenge) to 5 (Major challenge). Over 70% of participants, considered the need for data privacy security and portability and cyber security risk to be the most major challenges. Approximately 60% deemed the clarity of ethical approach

around data sharing, assets and intellectual property (IP) and clear commercial arrangements to avoid conflict around exploitation of IP to be a major challenge. Two-thirds of participants ranked the need for internationally agreed standards and the question of insurance and liability as 4/5 on the Likert scale indicating that these challenges are slightly less significant than the four previously mentioned. On the other hand, the same proportion regarded the need for standardisation or interoperability of data (57%), regulatory compliance requirement (61%) and the need for original governance models that enable data and asset sharing (54%) to be neither a major nor a minor challenge. Moreover, an average of only 1.6% of participants rated any one of the nine challenges as a minor challenge.

Further questions focused on privacy and security challenges as they were determined to be the main challenge in the literature review. Therefore, participants were asked to rank the pertinency of the various methods used to safeguard citizens privacy and security (see Fig. 4). Over 90% of participants believed that educating citizens about the privacy and security risks involved would be beneficial. In contrast, only a third deemed consulting citizens to be a useful approach. Anonymity and privacy measures and cyber-security were also highly regarded as being valuable in confronting privacy and security issues, by over 85% of participants. Only 43% of participants deemed authentication and encryption to be a helpful approach and less than 30% of participants believed security monitory and access control as useful in safeguarding citizens' privacy and security.

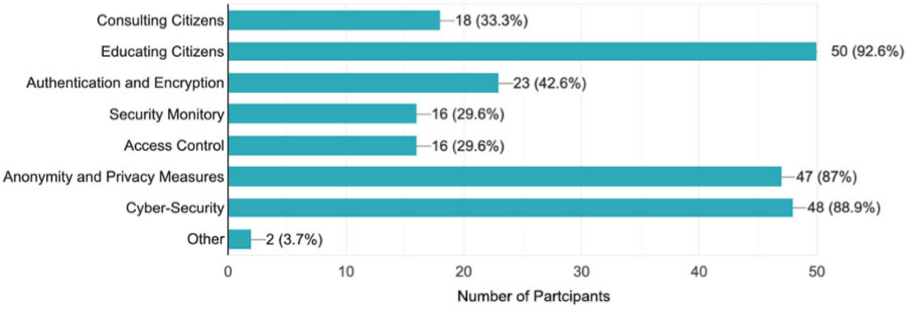

Fig. 4. Means of safeguarding the privacy and security of citizens

4.1.4 The Role of Governance, Regulations and Policies in Supporting Technological Advancement of Smart Cities

Various governance challenges that arise during the development of SCs. Participants were asked to rate ten of these challenges on a Likert scale from 1 (Not relevant) to 5 (Highly relevant). Around two thirds of participants consider lack of access to information and insufficient citizen awareness, engagement and participation to be highly relevant challenges. Moreover, no participants judge these two challenges to be not relevant at all. Likewise, no participants deem gaps between government and governed to be a completely irrelevant challenge, however a fewer percentage (56%) regard it to be highly relevant. Approximately 65% of participants believe that lack of access to technology and unbalanced geographical development are relevant challenges, whereas

slightly fewer (58%) think the same of unwarranted centralisation and absence of institutional coordination and instability in governance. Over half of all participants think of shortage of social services and no equity in access to opportunities and resources to be neutral on the Likert scale. However, the percentage (40%) of participants that consider no equity in access to opportunities and resources to be relevant or highly relevant is significantly higher than the percentage (28%) for shortage of social services and no equity in access. Only one participant considers low urban institutional capacity to be a highly relevant governance challenge, but at the same time, over 70% of participants think it to be neutral on the Likert scale and roughly 10% think it to be irrelevant or not at all relevant.

There are various existing laws and regulations that support the safe use of technology in Smart Cities, however, as technology progresses and develops, these laws should be amended simultaneously (see Fig. 5). Consequently, 18.5% of participants consider improvements to privacy law and 11.1% consider built environment law to do likewise. 3.7% of participants deem that ICT law and 1.9% suppose IP rights law should be upgraded. Those participants who chose other all consider that more than one law needs to be renewed in accordance with the level of the SC. Finally, when asked if the current laws and policies in place were enough to protect citizens against threats associated with SC technologies, 82% of participants responded that they were not sufficient, and that additional laws and policies were needed. Participants were invited to explain why as open answer, and reasons included: 'Regarding AI, a lot of policies and regulations have not been implemented to limit the possibilities of what can be created or done with AI. Although this may be beneficial, people can misuse AI for personal gain or unethical purposes.' and 'Technology evolution is lighting therefore requires new laws to protect the citizenry and counter unforeseen threats'.

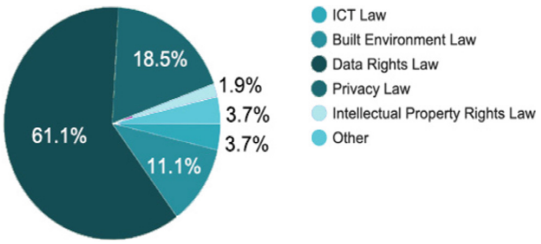

Fig. 5. Laws to be improved to support safe technology use in SCs

The literature review discerned several reasons for implementing SC policies. When asked to rank these reasons, the percentage of participants that ranked each reason to be the most important is as follows: Data protection and usage (69%), Privacy and personal rights protection (50%), Reliability and Liability (15%), Information security (13%), and Conflict of interest (13%).

The implementation of a SC and the technologies employed within it, involved several stakeholders. However, only some of these stakeholders need to be involved in the creation of policies and regulations surrounding the use of technology in SCs (Refer to Fig. 6). According to over 90% of participants, city and national governments must

be involved in forming policies and regulations. Two thirds of participants deemed that research institutions should also be involved. Only 50% of participants think that energy providers, telecom providers, technology vendors and banks and insurance companies should be involved. This could be because these organisations are usually privately owned, hence might develop policies and regulations with self-bias. Similarly, even fewer (32%) participants believe that investors should be involved because they could devise policies and regulations for their own financial gain. Approximately 40% of participants consider that universities and schools, digital agencies, construction companies and public transport providers should contribute to policy and regulation development while around 30% think that start-up incubators, logistic providers, health-care providers should be involved. Participants also suggested other relevant stakeholders such as citizen (representatives), technological specialists, national standard bodies, innovation agencies, planners and consultants.

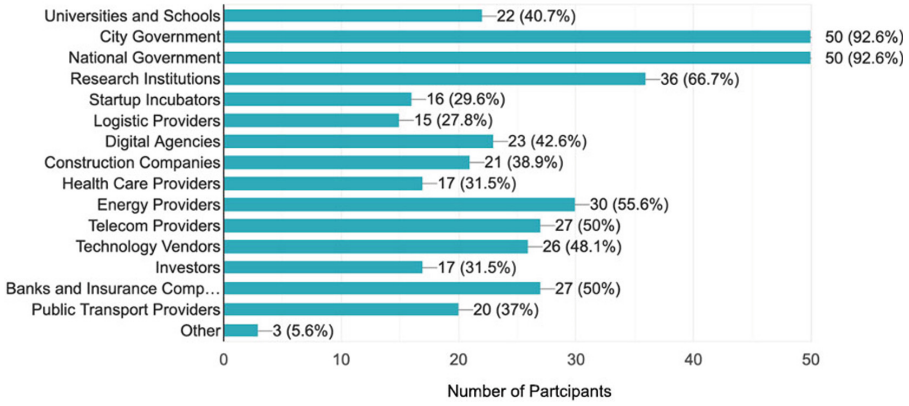

Fig. 6. Stakeholders to be involved in the creation of policies and regulations for SCs

4.2 Qualitative Results

Out of the 54 participants, 8 (hereby referred to as participant A-H) volunteered to participate in a follow-up interview.

4.2.1 Benefits and Drawbacks of the Technological Drivers in Smart Cities

Participant A believes that 'the purpose of SCs is to improve citizens QoL and technology enables cities to have a better quality of opportunities from automation to efficiency gains'. Likewise, participant E says that 'automation and efficiency gains provide a better quality of opportunities', just as participant G believes that 'technology will improve efficiency therefore improving citizen experience'. In the opinion of participant D, 'a city's services can only improve by measuring the current performance to make future improvements. This is enabled by technologies that collect data by digitally monitoring what the city is doing.' Correspondingly, participant B says that 'the purpose of technology is to augment services, provide insights and help with policies.' However,

participant F mentions that 'the workforce should be reskilled as public services get automated.'

Participant C questions the technology-expense use case, 'that is whether or not a technology will reduce cost or cause improvement'. Similarly, participant G asserts that 'it is important to question if there is a good ROI for each technology'. Multiple participants mentioned the social issues that arise with the implementation of innovation technologies, for example citizen's acceptance of using individual and amalgamated data. Additionally, participant D states that 'privacy concerns are huge challenge for implementation followed by legislation and policy. Moreover, security and hackers should not be a problem if the other factors are resolved'. Participant F goes on to add 'the question of how to engage the market is another challenge'.

4.2.2 Privacy and Security Challenges

According to participant D, 'standards are extremely useful in addressing security challenges'. Participant H believes 'it is straightforward to introduce new standards, but the challenge lies in getting the standards through regulatory compliance and getting government approval'. However, participant A affirms that 'there are already a number of international agreed IT standards, and it would only be a challenge if there are many new standards to approve of'. Equally, participant B asserts that 'standards regarding data privacy and security already exist' and suggests that 'GDPR could give guidance for handling privacy and security concerns around data'. Participant H says that 'maintaining data privacy is all about permissions and who access to the data. Hence information should only be revealed on a need-to-know basis'.

'The necessity for standardisation of data and how SCs across the nation and eventually the world is interoperated, is a longer-term problem' according to participant C. Equally, participant F says that 'we need to find a set of things that can be used and re-used in future SCs to make them all uniform to each other'. Participant H believes that 'the challenge of cyber security risk lies in the managing the perception of how the population views it'. Likewise, participant G states that 'the clarity of ethical approach around data sharing, should not be a challenge with appropriate perception management'. Participant D raises 'the question of insurance and liability if the private sector is involved, and challenges how the liability would be allocated between government, private and public sector and how risk vs reward would be managed'.

Participant C considers 'new governance models to be a challenge because a new set of skills and new organisational structures are required to come up with them.' Similarly, participant A says that 'current governance models are not set up for automation'. Participant A tells that 'to escalate decision making, citizen engagement is necessary in governance structure'. Participant F deems it to 'be in the governments best interest to avoid IP problems, hence when they employ private sector capabilities, they must ensure the company to share the IP to avoid exploitation'.

4.2.3 The Role of Governance, Regulations and Policies in Smart Cities

Participant A considers 'low urban institutional capacity to be one of the biggest concerns because essentially, existing structures need to be transformed into new technologically

driven structures'. Equally, participant H asserts that 'there is a lack of awareness with regards to the breadth and depth of what is best practice. Therefore, people are starting from scratch rather than looking at where there already is good practice'. Participant B adds that 'best practices have been drawn out of working with local authorities, and the best practice templates of already resolved issued can be followed'. Participant C states that 'the economic and political view is the most influential one, and the challenge lies in settling the debate between politics and technology'. Moreover, participant D affirms that 'if there is sufficient urban institutional capacity, there will not be any problems of instability in governance'. Besides, according to participant E, 'the perceived gap between government and governed can be reduced with the SC concept'. Participant F says, 'another challenge is that local authorities are often inward focused, hence don't see the world from a citizen's perspective of consider what services citizens want to consume and how they can use technologies'.

All eight participants agreed that additional laws and policies were necessary to protect citizens against the threats of innovative technologies. Though, participant F suggested that 'standards, voluntary agreed best practices are an alternative to laws and regulations'. Equally participant B says that 'it is quicker to create and approve of standards than it is to pass a new law'. Conversely, participant C states that 'standards sit hand in hand with legislation as governments sponsor or endorse standards'. Likewise, participant B reveals that 'the PAS180 range is a set of BSI (British Standards Institution) standards commissioned by the government to advice local authorities with regards to SC development'. A number of participants affirmed that most importantly, 'citizen engagement was necessary in devising new laws and policies'.

5 Discussion

SC technologies such as smart-syncing traffic lights, have the potential to alleviate traffic jams in congested cities [13]. Moreover, IoT sensors on physical infrastructure, can be employed to forewarn any problems so that reparations can be undertaken before breakdown [19]. The participants of this study would agree, as results demonstrate that the SC benefits that technology has the largest impact on are better traffic flow and renewed infrastructure. Various technologies and data from SC applications can be used to reduce the rate of crime across cities [17, 18]. Contrastingly, the study shows technology to be less influential in enabling safer cities. This potentially reflects on the fact that rather than being directly influenced by technology implementation, safer cities are result of other factors. For example, technology enables the improvement of mobility, social and economic equality, with crime rates diminishing as an after-effect.

Air quality can be improved, and energy saved by decreasing vehicular emissions through SC applications [13]. Likewise, the study reveals that the two challenges that can primarily be tackled through SC implementation are air pollution and urban congestion. By way of a positive chain reaction, some using SC technology to tackle certain challenges, could have a more extensive positive over-all effect. For example, reducing urban congestion not only reduces greenhouse gas emissions and noise pollution but also improves QoL by reducing citizens' commuting time.

SC technologies have markedly changed the concept of personal privacy [24]. The organisations who collect citizens data for SC development purposes also hold a great

deal of power and responsibility and the concern lies in data misuse or disclosure [25]. Comparably, the study determines that the biggest technological challenges in SCs are security, hackers and privacy concerns. In contrast, the survey demonstrates that interoperability and funding of SC technologies are less of a challenge. This could be because as experts working in the field of SC, they have a better comprehension of how various technologies function together and witness SC projects being funded on a regular basis. Even so, interoperability plays a key role in BIM, as the data held in a model is only useful when exchangeable [48], and the IFC standard is one of the foremost ways to achieve BIM interoperability [49].

Managing the large amounts of data and maintaining the privacy of citizens are issues of significant matters in SCs [24]. BIM plays an essential part in methodically analysing and classifying the large amounts of data produced by sources including people, machines and infrastructure on a daily basis. BIM, is able to amass a building's geometric and semantic information over the course of its life-cycle and research shows that it has the potential to catalyse SC development [50]. However, BIM is not able manage the big data produced by SCs, unaided [51], therefore necessitating BIM integrated solutions with technologies including IFC, 3D point cloud, City GML, Application Programming Interface (API). The participants of this study agree that the biggest privacy and security concerns are necessity for data privacy, security and portability, cyber security risks and the issues surrounding the sharing of data, assets and IP. While the collection of citizens' data is a prerequisite of SCs, technologies such as encryption through blockchain can protect and keep the data anonymous. Contrarily, study findings show that the requirement for regulatory compliance and for governance models that facilitate data sharing and decision making to be much less significant. This perhaps insinuates that although technology operations follow correct the problem lies in the illegal undertakings that infringe on citizens' data and violate their privacy.

SC policies are key to increasing a cities productivity, cumulative knowledge and economic output [32]. On the other hand, the study indicates that the foremost reason for implementing SC policies is for the protection of data usage. While both innovative and security reasons are relevant motives for enforcing policies, the discrepancy can be explained by the fact that multiple choice options available to the participants, focused on the policy-making that provided safety and security. Standards can both enable and inhibit SC innovation [52]. An interconnected series of standard changes must evolve to allow smarter cities and policy makers to achieve their objectives. This evolution involves the creation of new standards and the maturation of those already in existence [53].

The responsibility of re-evaluating and establishing new regulations lies with city leaders and national policymakers, however they should be supported by civil society organisations, technology vendors and private companies. Although the study establishes that city and national governments should be involved in policy and regulation creation surrounding the use of technology in SCs, it conversely shows that it is not as essential for stakeholders such as investors, health care providers, start-up incubators and logistics providers, to be involved in the creation of policies and regulations. Given that many of the study participants are part of these stakeholder groups, it perhaps suggests that

they either do not want the responsibility of or do not feel well enough informed to be involved in creating new regulations.

Legal and regulatory requirements should be up to date with the latest technologies, particularly for SC propositions to acquire investments [34]. The study confirms that primarily, the data rights law needs to be improved followed by privacy laws. According [39], SC agendas could be delayed or obstructed without the necessary legal frameworks. SC technologies are developing rapidly, however getting new legislation approved is a lengthier process. To overcome this obstacle, internationally agreed standards can be more easily established instead.

6 Conclusion and Future Work

The study confirmed that technologies play a significant role in the implementation of SCs bringing numerous benefits including better flow of traffic, better-quality infrastructure, more efficient public services and improved energy efficiency. These benefits contribute towards the inclusion aspect of UN 2030, SDG #11. However, there are certain challenges associated with the use of technologies in SCs, most notably maintaining the security and privacy of citizens' data. The primary solutions to safeguarding citizens' privacy and security in SCs are educating citizens, implementing anonymity and privacy measures and ensuring cyber-security. To maintain data privacy, it is suggested that the data is stored anonymously, and that information is only revealed on a need-to-know basis. Moreover, internationally agreed standards are a useful tool to address security challenges, as several ICT standards already exist. Although it is uncomplicated to initiate new standards, the consequent challenge is progressing the standards through regulatory compliance and obtaining government approval. This research also confirmed that there are not enough policies and laws in place to protect citizens against threats, making this a topic for further research. Finally, it was found that the biggest governance challenges in the development of SCs were the disparity between the government and the governed, lack of access to information and inadequate citizen awareness, engagement and participation.

It should be noted here that there are certain limitations to the research findings, stemming from the sample size. Further research can investigate a larger sample with participants from other countries too. Moreover, more work should be done to investigate how the privacy and security challenges can be faced. Further investigation could therefore determine a strategy to overcome these challenges and reap the benefits of SC technologies through new SC governance, regulations and policies.

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